Science & Technical Advisory Committee
Issue Paper 5, April 2008
Forecasting:
Estuarine Responses to Climate Change

Position: The multiple components of changing climatic conditions (e.g., rising temperatures, rising sea level, changes in precipitation and storm patterns) will have an impact on the physical and biological components of the Albemarle-Pamlico Estuarine System. Resources should be directed toward establishing baseline datasets to monitor changes, and focused research and modeling to improve understanding and forecasting ability, in order to facilitate responsible management policies.

Supporting Statement: The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2007) states that, "warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level." Additionally the report states that it is clear that a major portion of the warming is anthropogenic, that is, resulting from the addition of greenhouse gases to the atmosphere due to human activities (IPCC 2007). A consequence of climate change is rising sea level (due to melting ice sheets, glaciers, and thermal expansion of the ocean water), changing cyclonic storm patterns (e.g., increased hurricane intensity), changes in precipitation patterns, and increasing temperature. These factors represent drivers of coastal processes, so any change in these drivers will necessarily impact the processes and alter the coastal system to differing degrees, on a variety of spatial and temporal scales. Following is an explanation of the drivers and expected possible responses.

Drivers

Sea-Level Rise

Relative sea level in northeastern North Carolina is rising at an annual rate of ca. 3 to 6 mm based upon tidal records and analyses of marsh peats (Zervas 2004, Kemp et al. 2006). These annual rates of rise reflect the global rate (presently ca. 3.1 ±0.7 mm) since 1993, based upon TOPEX/Poseidon satellite altimetry data (Church and White 2006), glacio-isostatic adjustment (ca. 1-2 mm in North Carolina, Peltier 2004), and regional subsidence due to sediment compaction. Due to increased global temperature, sea-level rise rates will likely increase and may rise between 0.3 m to several meters above modern mean sea level by the year 2100 (IPCC 2007, Overpeck et al. 2006).

Storm Intensity and Frequency

There is growing evidence that warmer global temperatures are already increasing the destructive potential of hurricanes (Emanuel 2005) thus increasing the number of hurricanes that reach category 4 or 5 (Webster et al. 2005).

Annual Average Precipitation

Global warming is predicted to alter precipitation patterns globally (IPCC 2007), likely resulting in more intense rainfall in a given storm system, but also possible intensified periods of drought.

Temperature

An increase in annual average water temperature is expected with global warming.

Responses

Physical Systems

- Increased rates of coastal erosion on ocean and estuarine shorelines;
- Possible disruption of continuous barrier island segments by formation of breaches and new inlets;
- General salinity increase in estuaries in response to drought, long-term sea-level rise and barrier changes;
- Possible rapid salinity increase in response to threshold collapse of barriers in response to major storm impacts;
- Alteration of estuarine circulation patterns due to changing salinity and temperature structure.
- Greater susceptibility to thermal stratification and hypoxic bottom waters, resulting in increased fish kills.
- Possible increase in tidal prism, accelerating estuarine shoreline erosion, modifying sediment transport and wetland communities, and increasing flooding of low-lying areas;
- Wetland migration and accretion, net losses in human modified areas resulting from bulkheads or other obstructions to migration;
- Reduced carbon storage in wetland soils (peats) due to flooding by saline water, increased sulfate reduction, increased organic matter degradation, increased erosion.

Natural Biological Systems

- Cascading impacts on aquatic ecosystems (plankton, nekton, benthos, submerged aquatic vegetation (SAV), wetlands) via changes in salinity, temperature, circulation, stratification, hypoxia;
- Expected community change and migrations;
- Changes in SAV distribution (e.g., eel grass replaced by turtle grass) and emergent vegetation;
- Increased number of threatened and endangered species with possible extinctions;
- Expansion of the range of exotic species (e.g., Lionfish, snakehead fish, Codium in mesohaline regions, Phragmites). Additionally, it will become necessary to identify exotics before they dominate and produce detrimental effects, and distinguish between them and the natural succession in response to global warming and barrier/estuarine changes.

Human Systems

- Changes to coastal development patterns with associated concerns regarding preservation of infrastructure, coastal hardening, water resources, drainage ditches, surface water impacts, and water management structures.
- Changes to social and economic structures of coastal communities; loss of fisheries, tourism, agriculture, silviculture, infrastructure, property and associated tax base; emigration.
- Increased introduction of toxins into coastal system as coastal communities are increasingly flooded.

Recommendations

In light of the complexity and interdependent nature (i.e., feedbacks) of the processes and responses, as well as a general lack of baseline data, we cannot currently forecast the magnitude and extent of changes to the physical or biological systems with a high degree of certainty. Therefore, an increase in baseline datasets, monitoring programs, focused research efforts, and modeling is recommended in order to increase our understanding of the systems, and provide the most accurate forecasts possible.

References

Church, J. and N. White. 2006. A 20th century acceleration in global sea-level rise. Geophysical Research Letters 33, L01602, doi:10.1029/2005GL024826.

Emanuel, K. 2005. Increasing destructiveness of tropical cyclones over the past 30 years. Nature 436:686-688.

IPCC. 2007. Intergovernmental Panel on Climate Change Fourth Assessment Report: Climate Change 2007: Synthesis Report. http://www.ipcc.ch/ipccreports/ar4-syr.htm

Kemp, A. et al. 2006. Reconstructing relative sea-level on the Outer Banks, North Carolina: a microfossil based transfer function approach. GSA Abstracts with Programs 38:226.

Overpeck, J.T. et al. 2006. Paleoclimatic evidence for future ice-sheet instability and rapid sea-level rise. Science 311:1747-1750.

Peltier, W.R. 2004. Global glacial isostasy and the surface of the Ice-Age Earth: the ICE5G (VM2) Model and GRACE. Annual Review of Earth and Planetary Sciences 32:111–149.

Webster, P.J., G.J. Holland, J.A. Curry, H.R. Chang. 2005. Changes in tropical cyclone number, duration, and intensity in a warming environment. Science 309:1844-1846.

Zervas, C.E. 2004. North Carolina bathymetry/topography sea level rise project: determination of sea level trends. NOAA Technical Report NOS CO-OPS 041. May 2004. 31 p.